# Summary of CRC E-67 Effects of Ethanol & Volatility Parameters on Exhaust Emissions

**CARB Predictive Model Workgroup Meeting**

**February 14, 2006**

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# E-67 Project

**Objective**:

The goal of this project was to expand the database of information available on the impacts of gasoline volatility parameters and ethanol content on exhaust emissions from recent model light-duty vehicles. Regulated emissions were measured using standard exhaust emission tests. Speciated emissions were measured on a subset of the test fuels. The test fuels varied in ethanol content and in mid-fill and back-end volatility, as measured by T50 & T90.

- Project timeline: late 2002 - early 2006
- Contractor: University of California-Riverside CE-CERT (College of Engineering-Center for Environmental Research and Technology)
- Report released: February 3, 2006

# E-67 Project Design - Specifics

## Vehicle Set: CA-Certified 2001-03 MY

**Description of Test Vehicles**

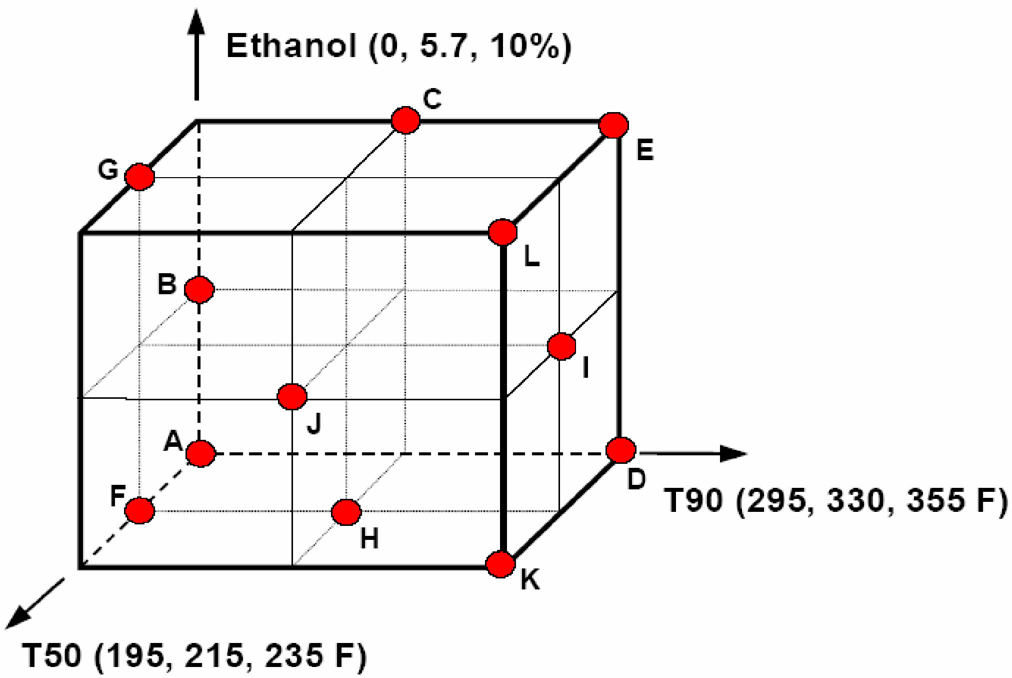
| # | MY | OEM | Model | CA Cert | Type | Engine | Mileage | Engine Family |
|---|---|---|---|---|---|---|---|---|
| 1 | 2002 | Ford | Taurus | LEV | PC | 3.0 L | 19,414 | 1FMXV03.0VF4 |
| 2 | 2003 | Chevrolet | Cavalier | LEV | PC | 2.2 L | 28,728 | 1GMXV02.2025 |
| 3 | 2003 | Ford | F-150 | LEV | LDT | 4.6 L | 13,856 | 3FMXT05.4PFB |
| 4 | 2003 | Dodge | Caravan | LEV | LDT | 3.3 L | 18,342 | 3CRXT03.32DR |
| 5 | 2003 | Ford | Explorer | LEV | LDT | 4.0 L | 16,445 | 3FMXT04.02FB |
| 6 | 2003 | Chevrolet | Trailblazer | LEV | LDT | 4.2 L | 13,141 | 3GMXT04.2185 |
| 7 | 2002 | Toyota | Camry | ULEV | PC | 2.4 L | 14,731 | 1TYXV02.4JJA |
| 8 | 2003 | Buick | LeSabre | ULEV | PC | 3.8 L | 10,364 | 3GMXV03.8044 |
| 9 | 2001 | VW | Jetta | ULEV | PC | 2.0 L | 28,761 | 1VWXV02.0223 |
| 10 | 2003 | Ford | Windstar | ULEV | LDT | 3.8 L | 20,523 | 3FMXT03.82HA |
| 11 | 2003 | Chevrolet | Silverado | ULEV | LDT | 5.3 L | 10,298 | 3GMXT05.3176 |
| 12 | 2003 | Honda | Accord | SULEV | PC | 2.4 L | 12,432 | 3HNXV02.4KCP |

**Vehicles equipped with catalysts aged to 100,000 miles for testing.**

# E-67 Project Design - Specifics

## Fuel Set:

- 12 fuels with 3 levels of ethanol, T50 & T90.




**General Fuel Properties**

| Property | Limits |
|---|---|
| RVP | 7.5-7.8 psi |
| FBP | <437 °F |
| RON | 91-95 |
| MON | 83-87 |
| (R+M)/2 | 87-91 |
| Aromatics | 23-27% |
| Benzene | 0.9-1.0 wt. % |
| Olefins | 8-12% |
| Sulfur | 15-20 ppm |

*Fuels met D4814 and contained a detergent pkg*

# E-67 Project Design - Specifics

**Test Protocol**:

- Standard FTP testing used (40% tank fill & LA4 prep before overnight cold soak)
- Randomized fuel test order within each vehicle
- Each fuel/vehicle combination tested twice
- Auto/Oil outlier criteria used to determine need for third tests
- Organic gas speciations run on fuels D, E, K & L

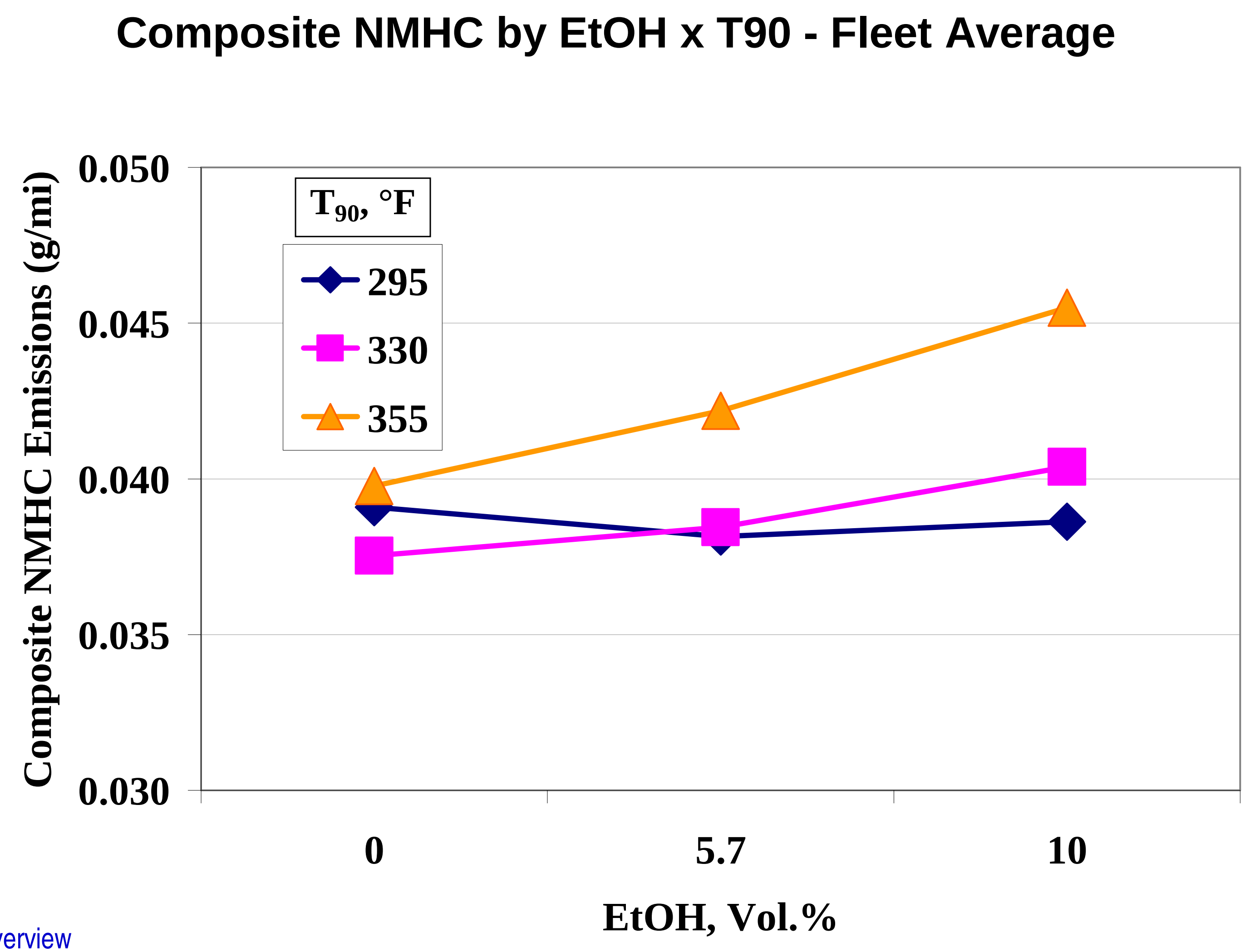
# E-67 Statistical Analysis

- Emissions analyses were run using the Proc Mixed procedure in PC/SAS.
- The primary analysis estimated regression coefficients for the fuel effects, with the levels of EtOH, T50, and T90 used as continuous variables within the model.
- Analyses used the natural logs of the data for the regulated emissions, NMOG and toxics.
- Effects are statistically significant if $p<0.05$ and are marginally significant if $0.05<p<0.10$

# E-67 Key Findings - NMHC

- A significant interaction was found between ethanol and T90.
- The interaction showed that NMHC increased with increasing ethanol content at the mid-point and high levels of T90, but was unaffected at the low T90 level.
- Alternatively, NMHC increased with increasing T90 at the mid-point and high levels of ethanol, but was unaffected at the zero level of ethanol.
- This interaction is illustrated on the next two slides.

# E-67 Key Findings - NMHC



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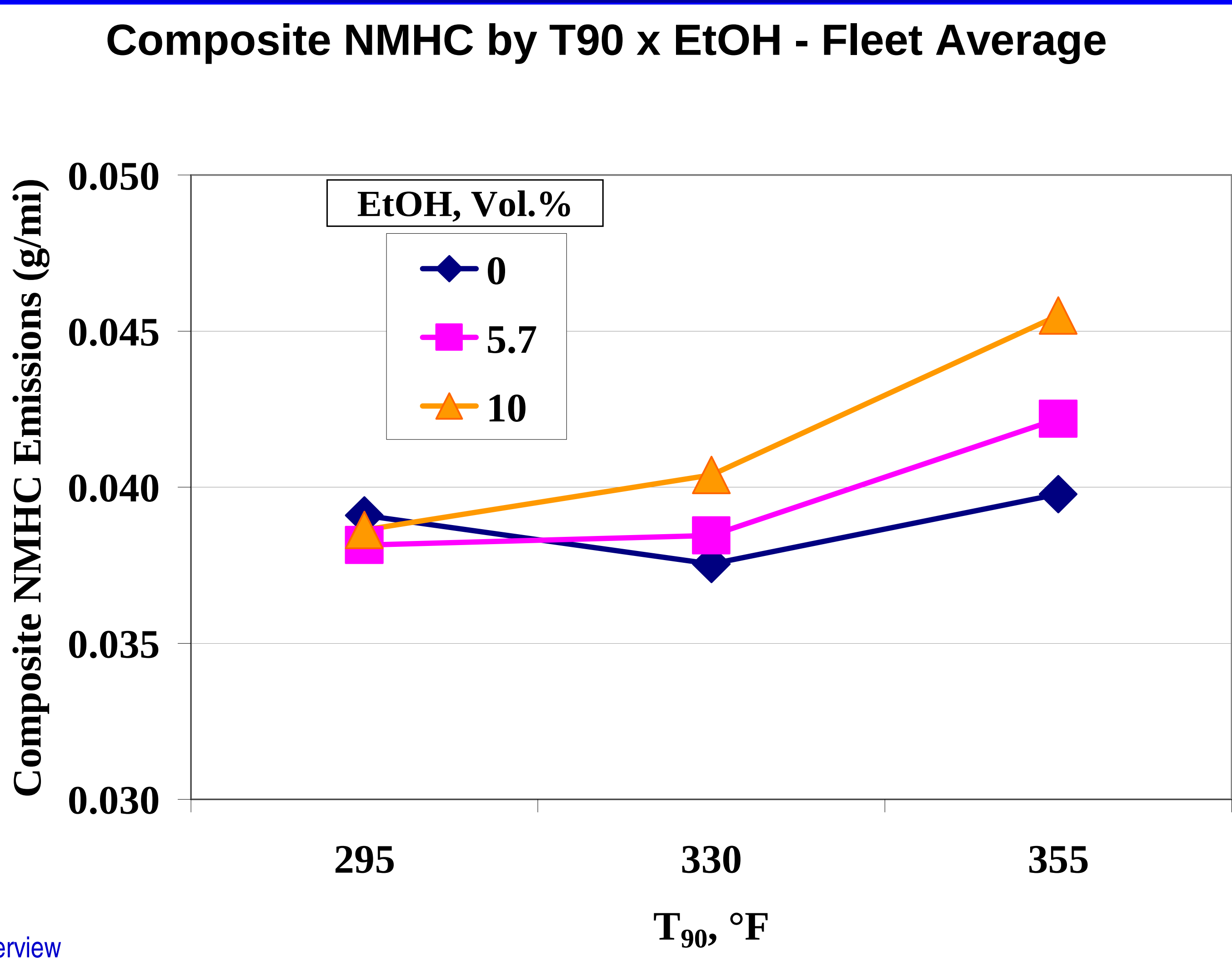
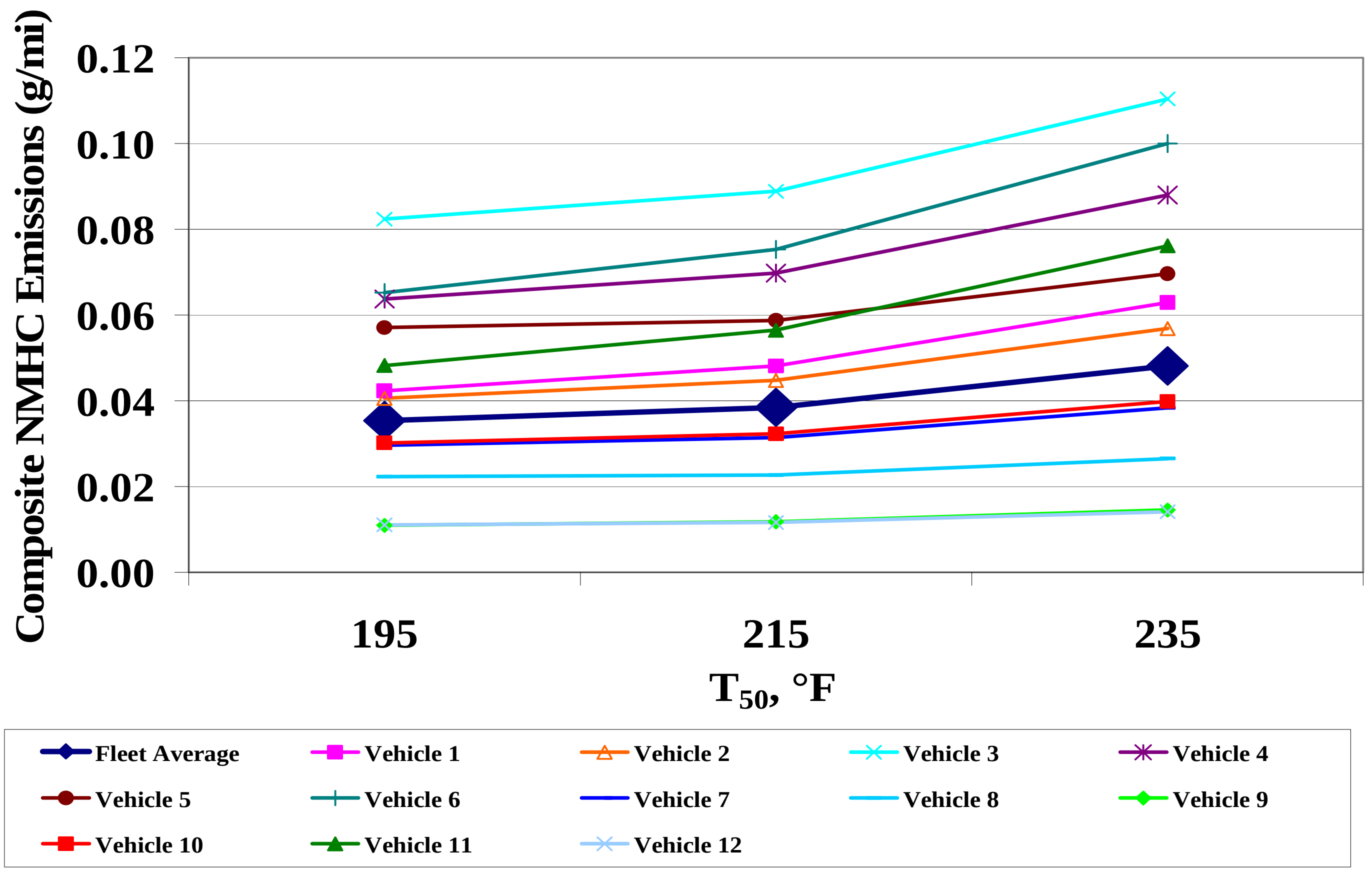


# E-67 Key Findings - NMHC

- NMHC increased with increasing T50.
- The fleet-average percentage increases in NMHC in going from the low and mid-point level of T50 to the high T50 level were 36 and 25%, respectively, as shown on the next slide.

# E-67 Key Findings - NMHC

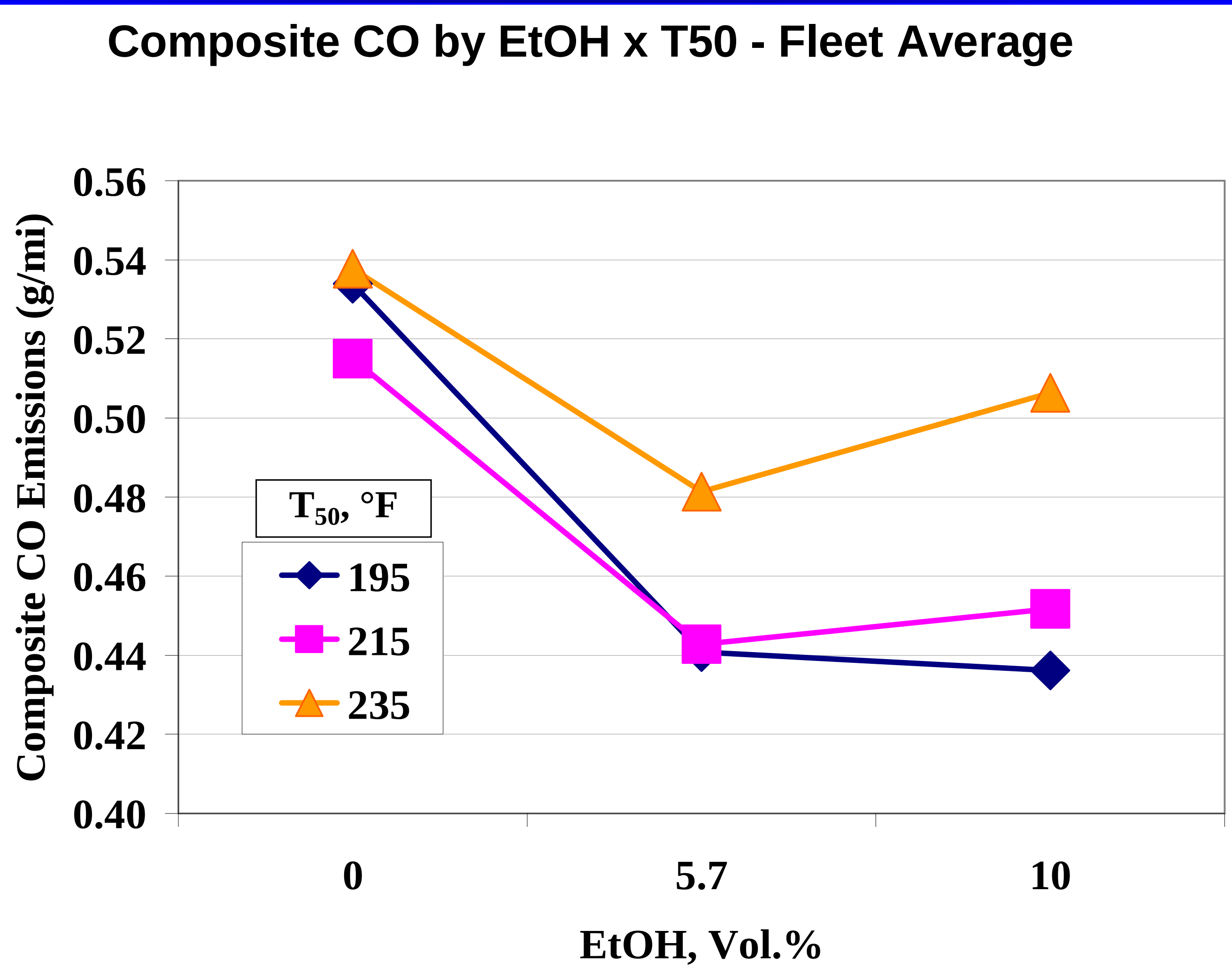
**Composite NMHC by T50 - Fleet-Average and Individual Vehicles**



# E-67 Key Findings - CO

- A significant interaction was found between ethanol and T50.
- The interaction showed that CO decreased as ethanol was increased from the zero to the mid-point level for all levels of T50.
- However, increasing ethanol from the mid-point to the high level produced little to no change in CO at the low and mid-point levels of T50, and increased CO at the high level of T50.
- Alternatively, CO increased with increasing T50 at the mid-point and high levels of ethanol, but was unaffected by T50 at the zero level of ethanol.
- This interaction is illustrated on the next two slides.

# E-67 Key Findings - CO



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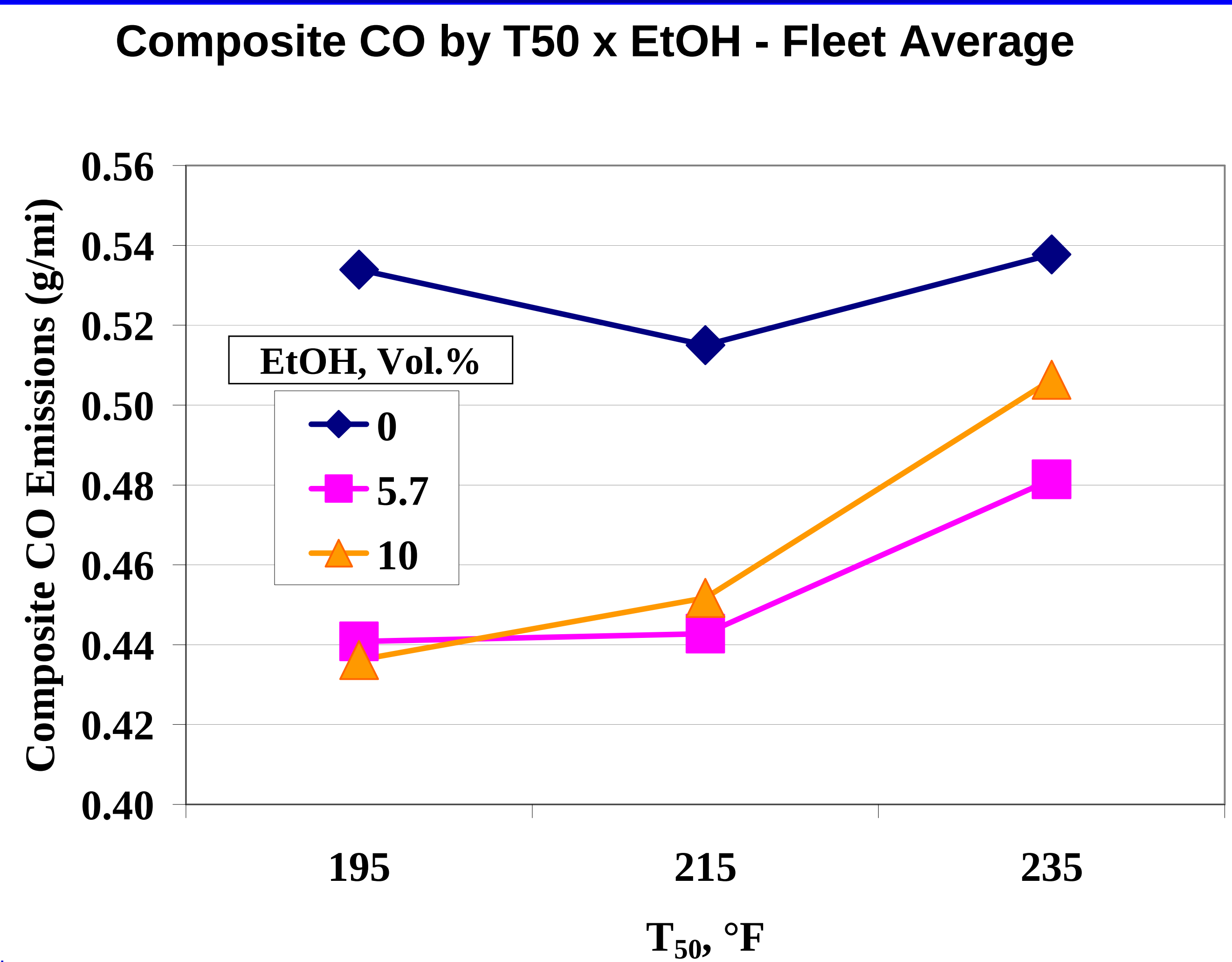
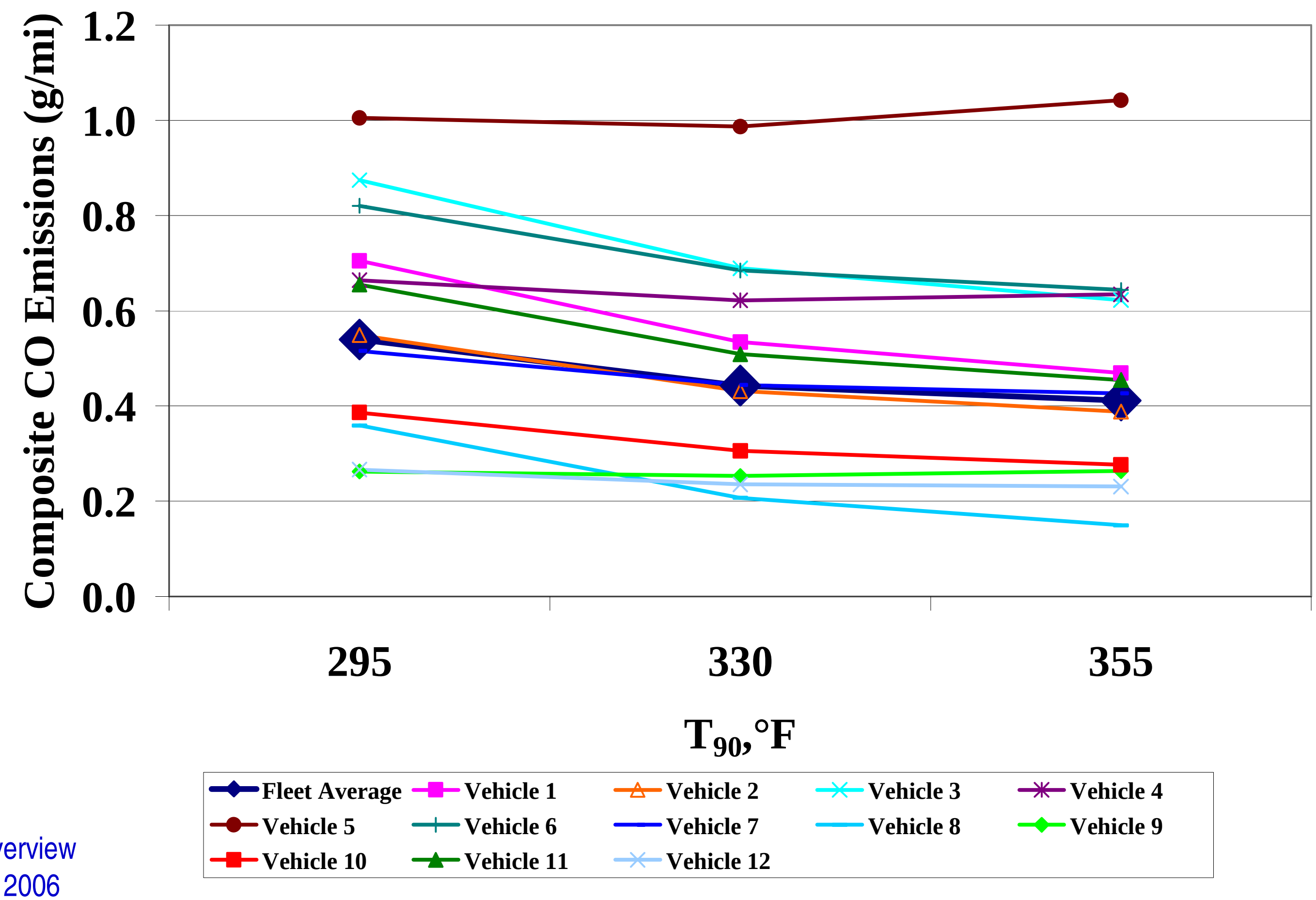


# E-67 Key Findings - CO

- CO decreased with increasing T90.
- The percentage decreases in going from the low and mid-point level for T90 to the high T90 level were 24% and 7%, respectively, as shown on the next slide.

# E-67 Key Findings - CO

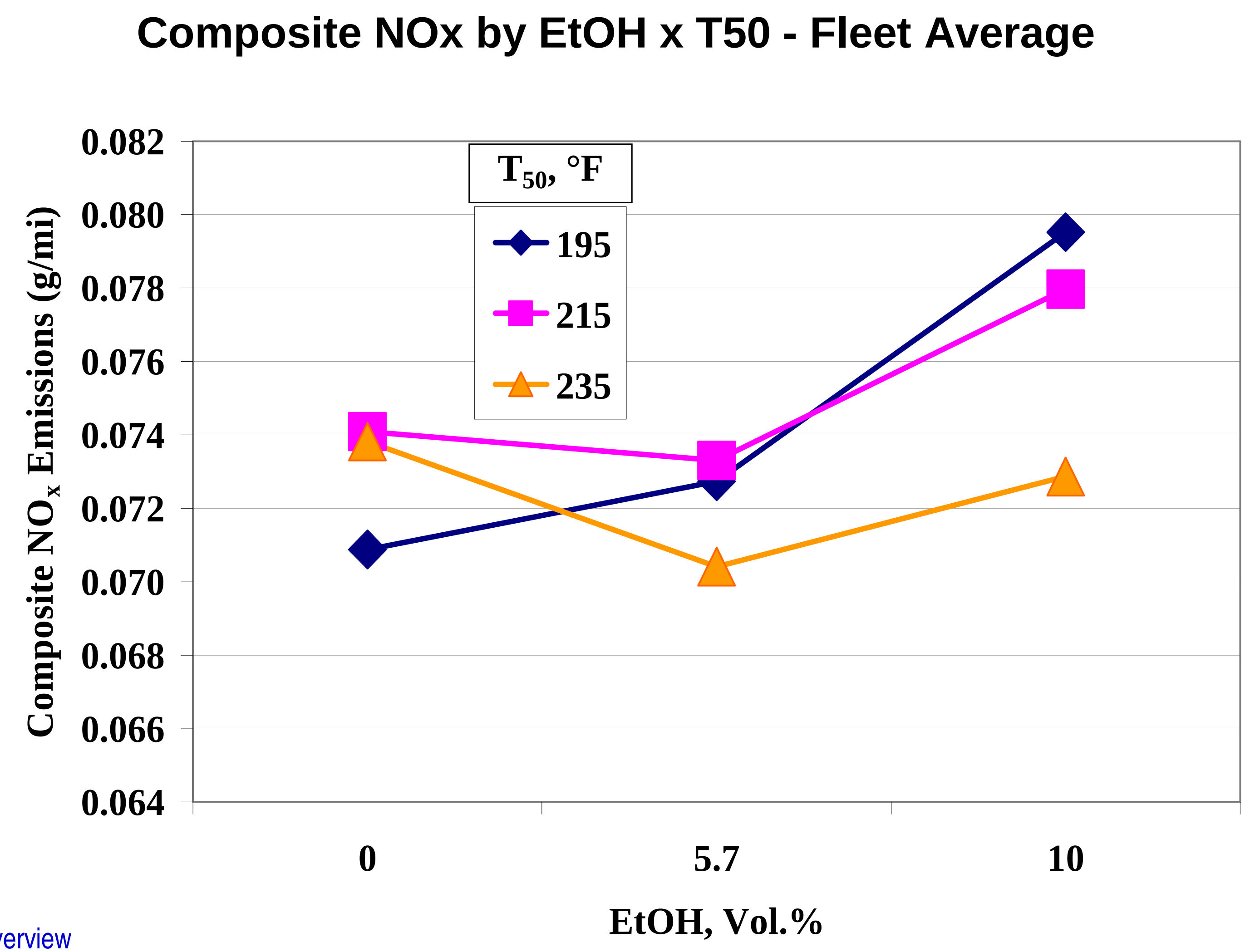
**Composite CO by T90 - Fleet Average and Individual Vehicles**



# E-67 Key Findings - NOx

- A significant interaction was found between ethanol and T50.
- The interaction showed that NOx increased with increasing ethanol content at the low level of T50.
- At the mid-point level of T50, NOx was largely unaffected as ethanol was increased from the zero to the mid-point level, but increased as ethanol was increased to the high level.
- At the high level of T50, NOx is largely unaffected by ethanol.
- Alternatively, NOx decreased with increasing T50 at the high level of ethanol, but was largely unaffected by T50 at the zero and mid-point levels of ethanol.
- This interaction is illustrated on the next two slides.

# E-67 Key Findings - NOx



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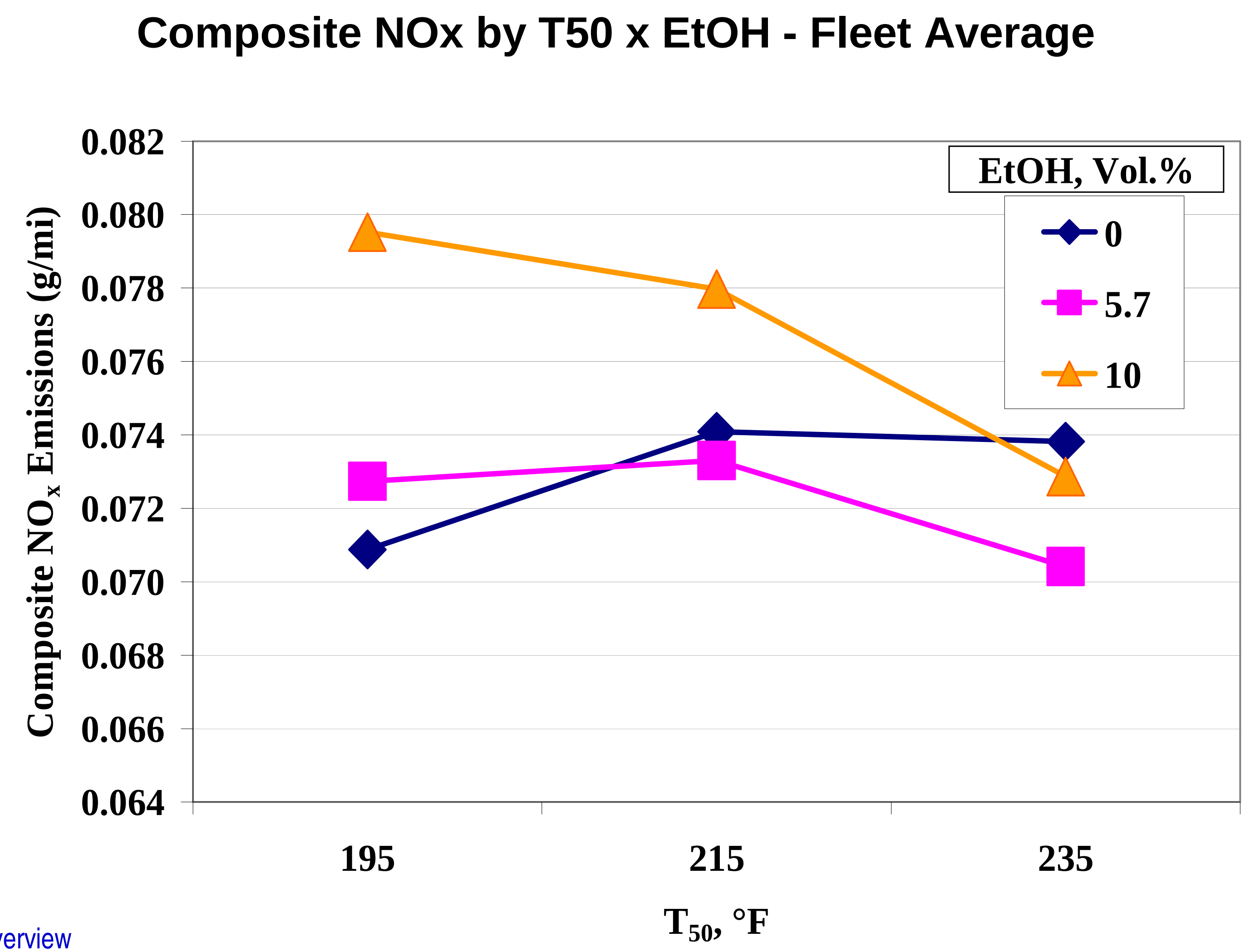

# E-67 Key Findings – NMOG & Toxics

**Caveat:**

The effects of ethanol and T50 on NMOG and toxics described on the next slide were only observed for the subset of fuels having the high level of T90. The results of this study do not permit any conclusions as to what effects T50 or ethanol might have on NMOG or toxics emissions for fuels having low or mid-point T90 levels.

# E-67 Key Findings – NMOG & Toxics

**NMOG:**
- Increased by 14% when ethanol was increased from zero to the high level.
- Increased by 35% when T50 was increased from the low to the high level.

**Formaldehyde**:
- Increased by 23% when T50 was increased from the low to the high level.

**Acetaldehyde**:
- Increased by 73% when ethanol was increased from zero to the high level.

**Benzene**:
- Increased by 18% when ethanol was increased from zero to the high level.
- Increased by 38% when T50 was increased from the low to the high level.

**1,3-butadiene**:
- Increased by 22% when ethanol was increased from zero to the high level.
- Increased by 56% when T50 was increased from the low to the high level.

# CRC E-67

- The E-67 final report and the dataset are both available on the CRC website at:

http://www.crcao.com/

- Click on "Recent Reports and Study Results"